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Valve Technology Arrangement of Cryopump: A Review

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Abstract
A cryopump or a "cryogenic pump" is a vacuum pump that pumps the trap gases and vapours by condensing them on a cold surface. Helium gas which is very light can only be pumped by Cryopump. Cryopump cannot be used when working for continuous operation as it pumps the effluent till the saturation state is achieved. Then the absorbed gases are to be collected through other mechanical pump through regeneration process. Hence, valve technology arrangement is incorporated with the cryopump in order to achieve the continuous pumping when two cryopump are used in alternate processes (i.e. absorption and regeneration). Various design of Valve technology arrangement is proposed by different researcher all over the world. This review paper focuses on the different proposed valve technology arrangement and elaborately explains the various components of valve technology and concludes the best possible arrangement that can be used in Cryopump.
Keywords*:* Cryopump, Valve technology arrangement

I. INTRODUCTION

SST-1 (Steady State Superconducting Tokamak) is a plasma confinement experimental device in the Institute for Plasma Research (IPR). The SST-1 project will increase India's stronghold in a selected group of countries who are capable of conceptualizing and making a fully functional fusion based reactor device. A tokamak, or tokomak, is a device uses a magnetic field to confine plasma in the shape of a torus. In order to produce a self-sustaining fusion reaction, the tritium and Deuterium plasma must be heated to over 100 million ˚C where in result producing high throughput of He and DT mixtures. Hence, there is a great requirement of pumping system capable of pumping at very speed.

Pumps having mechanical movement cannot be used for pumping as it has to be operated during the operation of the Tokomak, no motor or magnetic field is allowed in its vicinity. Also, Helium gas throughput cannot be pumped by mechanical pumps as the Helium gas is very light in nature. Hence, Cryopump is the only solution for pumping the effluent from the Tokamak.

Cryopump works by providing a very large surface area of material that is cooled to below the boiling point of most gases. Gas molecules that strike this cooled micro-Porous surface become attached and are removed from the gas phase, and are effectively "pumped" from the vacuum system. The active surface area of a cryosorption pump is typically made of charcoal. The pore size is appropriate for capture of the gases most predominant in the atmosphere. Low atomic weight gases, such as hydrogen, helium and neon have molecular diameters smaller than the 13Å pore size of the zeolite, and are captured by this material less effectively. Gas capture pumps of these types share a few operational characteristics. With use, they will eventually become "saturated" and will cease to pump- gases effectively. When this occurs, a sorption pump will either need to be "regenerated" or replaced.

Regeneration, the sorbent material will become saturated with gas molecules, and the pump's ability to remove gas from the vacuum system will rapidly deteriorate. When this occurs, regeneration may be performed by simply valving the pump off from the system, and allowing it to come to room temperature. Gases will be liberated from the charcoal surface, and will escape the pump body through the vent or pressure relief valve.

II. VALVE TECHNOLOGY ARRANGEMENT

The SST-1 (Steady State Superconducting Tokamak) requires an uninterrupted operation of the Torus Cryopumps. Therefore the cryogenic pumps have a integral valve arrangement with an opening and closing by a pneumatic actuator to separate the pump from the plasma for the regeneration of the accumulated gases.

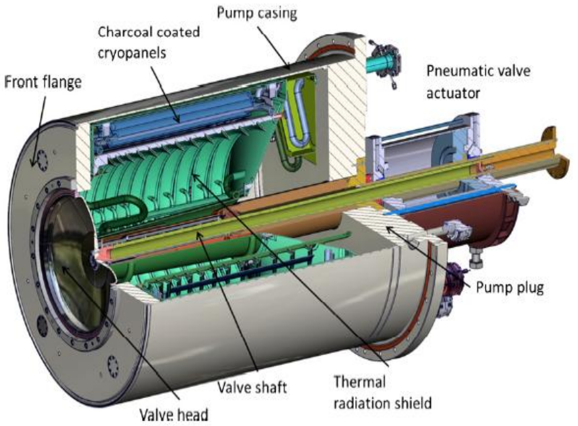

Figure 1 View of sectional cut of Torus Cryopump [M Dremel et al, 2013]

One of such design proposed by **M. Dremel et al, 2013** show the valve technology arrangement in which the valve shaft is sealed to the torus primary vacuum by a double bellows arrangement, which is designed for a stroke length of 0.45 m. The cryopumps pump the gases from the torus primary vacuum by accumulation to activated charcoal. The pump contains a charcoal surface of 11.2 m^2 made of 28 flat hydroformed stainless steel panels which are cooled to a temperature below 5 K in nominal operation. This pumping surface is surrounded by a thermal radiation shield to reduce the heat load to the low temperature circuit as much as possible but still keep a good pumping efficiency. [4]

Various valve technology arrangements are proposed by different researchers having different bellow arrangements for leak tightness purpose during regeneration process.

A. Mack et al., in his research paper "Design of the ITER torus cryopump", in 2002, proposed a ''nude'' style of cryopump (without integral pump housing) to maximize the usable space available. In this arrangement, the vacuum vessel port, the port closure flange and the internal valve disk form a vacuum boundary around the pump, which then allows regeneration when the inlet valve is closed. The Cryopanels of the pump are suspended from the vacuum vessel port closure flange to which is mounted a demountable sub-flange. On the back of this flange, the pump inlet valve actuator is installed. The pump inlet valve is mounted on the valve actuator drive shaft, which extend into the vacuum enclosure as shown in figure 2. [1]

When the valve actuator is extended, the inlet valve is sealed against the valve closure plate of the port, and when retracted, it allows a progressively opening of the inlet valve. The sub-flange is mounted on the vacuum vessel port flange using bolts for mechanical attachment and a welded lip seal for vacuum sealing. With the pump installed, the valve actuator is located in the port interspace vacuum. [1]

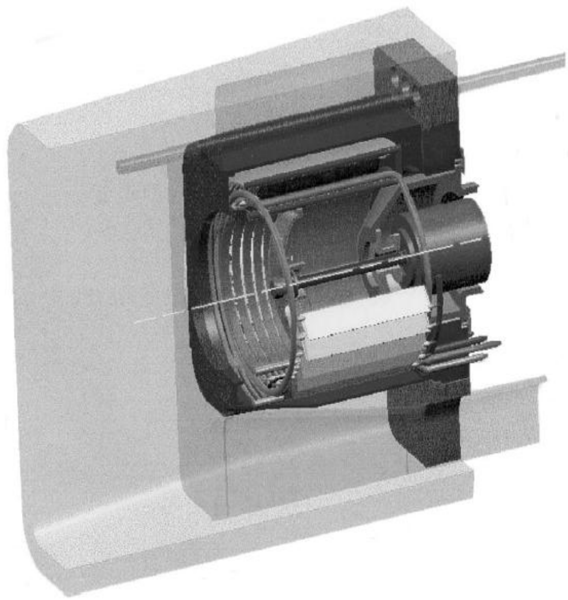

Figure 2 View of Torus cryopump [A. Mack et al, 2002]

V Hauer et al., in his research paper "Design of the ITER torus prototype cryopump" in 2007, proposed prototype pump featuring an integral inlet valve with a nominal diameter of 800 mm which can be closed during the plasma pulse operation for on-line regeneration. The valve consists of the valve disc, the valve shaft and the removable actuator assembly (see Figure 3). It can be throttled over the complete range with an accuracy of 1 mm. The maximum time for complete opening or closing is 10 s. The valve disc is cooled by a GHe flow at 300K and 1.8MPa. A double bellow and a double tubes structure enable to achieve the leak tightness and a double confinement around the valve shaft. All connections to outside be double sealed with a connection to the service vacuum system of ITER. The valve actuator as well as the outer part of the valve shaft can be removed to allow the remote handling of the pump. [2]

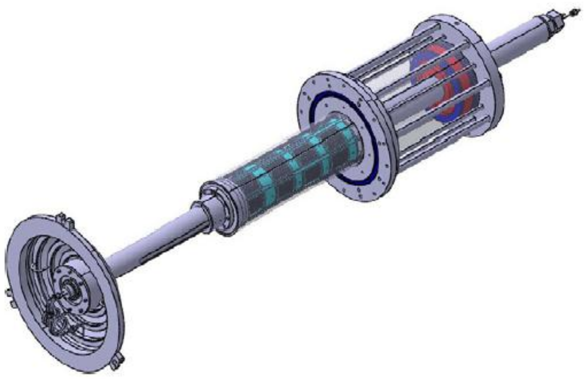

Figure 3 Inlet valve sub-assemblies [V Hauer et al, 2007]

M Dremel et al., in his research paper "The new build to print design of the ITER Torus Cryopump", in 2013 proposed the cryogenic pumps having a large integral valve with an opening diameter of 0.8 m operated by a pneumatic actuator to separate the pump from the plasma for the regeneration of the accumulated gases. The valve shaft is sealed to the torus primary vacuum by a double bellows arrangement, which is designed for a stroke length of 0.45 m. [4]

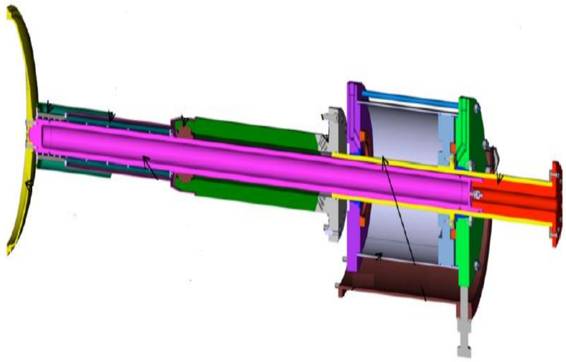

Figure 4 Valve assembly [M. Dremel et al, 2013]

The double vacuum barrier has been moved to the front of the valve shaft to operate the slide bearing in atmosphere hence a slide bearing which is industrially standardized and which will have a much higher reliability can be used. The bellows assembly consists of two bellows in a series connection to get a double barrier between the atmosphere and the primary vacuum of the torus. The interspace between the bellows will be connected to the Service Vacuum System of ITER and continuously controlled. For the stroke length of 0.45 m edge welded bellows are required. The conceptual design of the bellows assembly is shown in Figure 4 and it can be seen that one bellows are compressed while the other is extended. [4]

III. CONCLUSION

Initially, the two valve arrangements were used for maintaining the leak tightness in the cryopump chamber. Then the valve arrangements having metallic bellow are used for the leak tightness purpose. V Hauer in his research paper has shown single bellow arrangement while M. Dremel in his research paper has shown use of the double bellow in series arrangement for maintaining Vacuum inside the cryopump chamber. Hence suitable valve technology arrangement providing effective leak tightness should be selected considering system requirements, safety requirement and construction requirement.

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